THE MARS EXPLORATION ROVER PROJECT

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Abstract.

In mid-2003 NASA will launch two identical rovers to Mars. The Mars Exploration Rovers will be enclosed in Mars Pathfinder heritage cruise and entry stages. After landing in January and February 2004, the rovers will use their sophisticated set of instruments - the Athena Science Payload -- *to* search for and characterize geologic evidence of liquid water in the planet's past. These missions aim *to* test hypotheses for the presence of past water at two separate sites on Mars where conditions may once have been favorable to life. The landing sites will be selected on the basis of a community-wide intensive *study* of orbital data collected by the Mars Global Surveyor spacecraft and other missions. Possibilities might include former lakebeds or hydrothermal deposits. The instrument suite includes mast-mounted remote-sensing instruments: a color stereo imager (Pancam) and a thermal emission infra-red point spectrometer (Mini-TES). Mounted on the end of a robotic arm are four in-situ instruments: an Alpha-particle X-ray spectrometer (APXS), a Mössbauer spectrometer, a Microscopic imager, and a Rock Abrasion Tool (RAT). With far greater mobility than the 1997 Mars Pathfinder rover, these identical robotic explorers will each be able to trek up to 100 meters per day across the Martian surface, and characterize the landscape they encounter. The rovers' scientific instruments will be used to read the geologic record at each site, to investigate the role of past water, and to determine how suitable the conditions would have been for life. This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology under a contract with the National Aeronautics and Space Administration.

Introduction

In 2003, NASA will send two powerful new rovers on their way to two locations on Mars. The identical Mars Exploration Rovers (MER) will have greater mobility than the Mars Pathfinder rover Sojourner, being able to drive up to 100 meters per day. Each MER carries with it the Athena Science Payload. This set of instruments will allow the science team an Earth to read the geologic record at the two separate landing sites, to investigate the role of past water on Mars, and to determine how suitable the conditions would have been for past or current life.

Mission Overview

The MER spacecraft will be launched from Cape Canaveral, Florida in mid-2003, arriving at Mars in January and February of 2004. The interplanetary cruise and the entry, descent, and landing phases of the MERs will resemble that of the Pathfinder spacecraft. After releasing the cruise stage prior to atmospheric entry, the Viking-derived heat shield protects the spacecraft during initial deceleration. A parachute deploys from the back-shell to further slow the spacecraft and the heat shield is jettisoned. The lander is lowered from the back-shell on a bridle and a radar-altimeter on its underside measures the approach to the surface. In the final phase of landing, airbags are inflated around the lander, solid rockets on the back-shell fire to stop the vertical descent, and the bridle is cut. The airbags cushion the landing as the spacecraft bounces and rolls as far as one kilometer before coming to a stop. When it stops, the airbags deflate and retract and the petals will open up, bringing the lander to an upright position and revealing the rover.

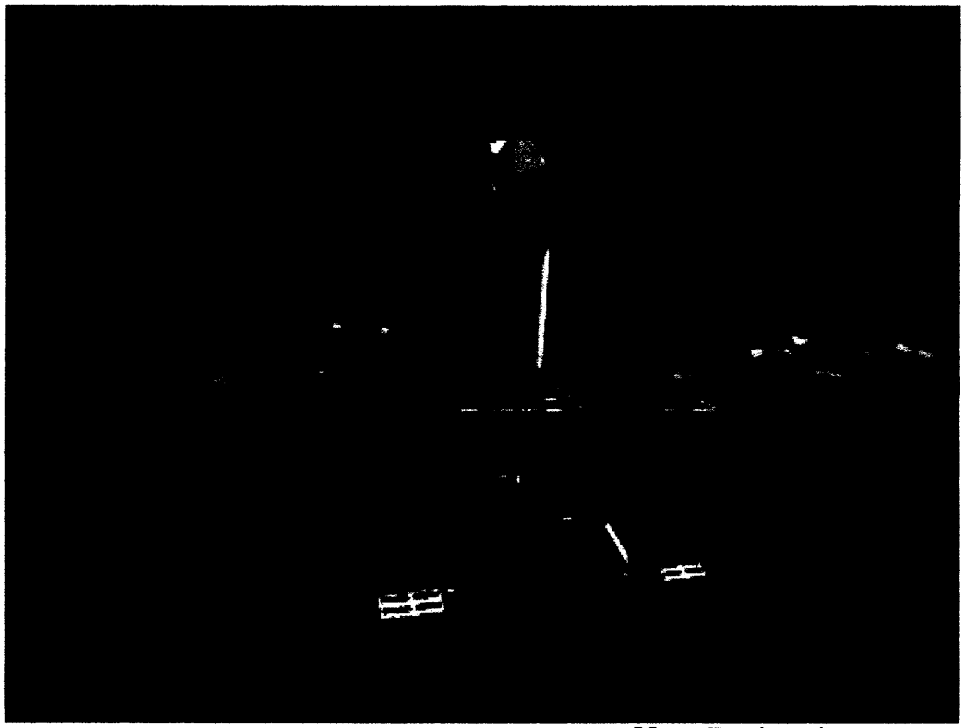

Figure 1. Graphic simulation by Dan Maas of a Mars Exploration Rover leaving the lander to explore the terrain

The landed portion of the MER mission features a design significantly different from Mars Pathfinder's. Where Pathfinder had scientific instruments on both the lander and the small Sojourner rover, the larger MERs will carry all their instruments with them. In fact, they will also contain the avionics used to fly the cruise stage to Mars. Immediately after landing, each rover will begin reconnaissance of its landing site by taking 360-degree visible color and infrared image panoramas. After careful analysis, each rover will then be commanded to leave the petal structure behind, driving off to begin its exploration (Figure 1).

Each MER will analyze rocks and soils using the Athena Science Payload. Using images and spectra taken daily from the rovers, scientists will command each vehicle to go to rock and soil targets of interest and evaluate their composition and their texture at microscopic scales. Initial targets may be close to the landing sites, but later targets can be far afield: early in the mission the MERs will be able to travel almost as far in one Martian day as the Sojourner rover did over its entire lifetime. Each rover has a mass of approximately 160 kilograms. Surface operations will last for at least 90 sols, extending to late April 2004, but could continue longer, depending on the health of the vehicles.

Science Goals

The mission seeks to determine the history of climate and water at two sites on Mars where conditions may once have been favorable to life. The sites will be chosen about a year before launch, on the basis of intensive study of orbital data collected by the Mars Global Surveyor spacecraft and other missions. Selection criteria will include clear evidence of ancient water, as indicated either by minerals that form under wet conditions or landscapes apparently shaped by water. Possibilities include former lakebeds or hydrothermal deposits. The rovers' instruments will be used to read the geologic record at the sites, and to evaluate how suitable the past conditions would have been for life.

Science Instruments

Each rover will carry an identical Athena Science Payload, which includes both mast-mounted remote-sensing instruments and instruments for in-situ analysis mounted on a robotic arm at the front of the rover. The mast instruments are the Panoramic Camera (Pancam) and the Miniature Thermal Emission Spectrometer (Mini-TES). The four robotic arm instruments are: an Alpha-particle X-ray spectrometer (APXS), a Mössbauer spectrometer, a Microscopic Imager, and a Rock Abrasion Tool (RAT). Like Mars Pathfinder, the Athena Science Payload on the MERs also includes a Magnet Array.

Pancam

The Panoramic Camera is a color stereo imager with a 1024 by 1024 pixel array which will be used to reveal the terrain around the rover, searching for evidence of the action of liquid water. Pancam's purpose is to allow the science team to interpret the geologic context of each landing

site. It will be used to help select the most promising rock and soil targets for more intensive study, and to pick new regions for the rover to explore. Its resolution is over three times better than that of the cameras carried on the Mars Pathfinder lander. Pancam is provided by NASA's Jet propulsion Laboratory (JPL), in Pasadena, California.

Mini-TES

The Miniature Thermal Emission Spectrometer (Mini-TES) will view the *scene* around the rover in the infrared, determining types and abundance of many different kinds of minerals. A particular goal will be to search for distinctive minerals that are formed by the action of water. Mini-TES is a point spectrometer, *that* is, it measures a spectrum from one spot at a *time*. Scanning in two dimensions to build up a panoramic *image*, Mini-TES will also be used in tandem with the Panoramic Camera to select science targets and to pick new areas to explore. The Mini-TES has two resolution settings, one approximately 25 Pancam pixels across and the other about 60 Pancam pixels across. Mini-TES is provided by Arizona State University in Tempe, Arizona.

Mössbauer Spectrometer

Mounted on the turret at the end of each of the MER's robotic ar, the Mössbauer Spectrometer will be placed against rock and soil targets. It will identify any minerals that *contain* iron, help to evaluate what role water played in the formation of these minerals, and help to discern the extent to which rocks have been weathered. The Mössbauer Spectrometer is provided by the Johannes Gutenberg University, in Mainz, Germany.

Alpha-Particle X-Ray Spectrometer

The Alpha-Particle X-ray Spectrometer is from the *Max* Planck Institute for Chemistry, also in Mainz, Germany. It will determine the composition of the rocks and soils *against* which it is placed by the MER robotic arm. This APXS instrument is an improved version of the instrument used by Pathfinder's Sojourner rover. It measures the concentrations of most major elements, allowing investigation of how rocks and soils formed and how they have been altered over time.

Microscopic *Imager*

The Microscopic Imager (MI) will reveal fine-scale *appearance* of rocks and soils, which can provide essential clues to how those rocks and soils were formed. For instance, the size and angularity of grains in water-lain sediments can reveal how they were transported and deposited. The MI is a 1024 by 1024 pixel array with spatial resolution of about 30 microns per pixel. The MI is provided by by NASA's Jet Propulsion Laboratory (JPL), in Pasadena, California,

Rock Abrasion Tool

The Rock Abrasion Tool provided by Honeybee Robotics, of New York, N.Y., will be mounted with the MI, *APXS* and MS on a turret at the end of the MER robotic arm. The RAT will grind

away to a depth of 5mm the outer surfaces of rocks, which may be dusty and weathered, allowing the other science instruments to determine the nature of rock interiors.

Magnet Array

The Niels Bohr Institute in Copenhagen, Denmark is providing a set of passive magnets which will capture Martian dust. Examination of the captured dust with the Pancam, Mössbauer Spectrometer and *APXS* will improve our understanding of the magnetic portion of Martian dust and the role of water, if any, in its formation, The experiment is an improved extension of the magnet experiments on the Viking Landers and Mars Pathfinder.

Other Rover Equipment

In addition to the Pancam and MI, each MER will also be equipped with a mast-mounted stereo pair of navigation cameras (Navcams), with forward and rear stereo pairs of cameras used for autonomous navigation and hazard avoidance (Hazcams), and a camera to track the position of the sun (Suncam). The Pancam and the Navcams are mounted atop the Pancam Mast Assembly (PMA) which also serves as a sort of periscope-mounting for Mini-TES's pointing mirror. The PMA is deployed once after landing and remains deployed during driving. It raises the Pancam viewpoint to about 120 cm above the surface.

The science team will use all the information available from the Athena Science Payload and the other MER cameras in an integrated fashion to evaluate the terrain at each of the landing sites and achieve the science goals of the MER mission.

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